

## **Hear and Now**

By Frank R. Lin, M.D., Ph.D.

*As a practicing otologic surgeon with a Ph.D. in epidemiology and a leader in research that examines hearing loss as a potent risk factor for dementia, our author tells us what we've learned and what we still need to know about the relationship between hearing loss and cognitive decline in older adults.*

When I was going through my otolaryngology residency at Johns Hopkins in the early 2000s, I was struck by the disparity between how hearing loss was managed in children and in older adults. In the case of the child, it was a medical priority to ensure access to a hearing aid so he or she could communicate optimally at home and in school, and such devices were covered by insurance. This approach was justified based on extensive research demonstrating that hearing loss could have a substantial impact on a child's cognitive and brain development, with lifetime consequences for educational and vocational achievement.

For the older adult, the approach was radically different, even if the degree of hearing impairment was the same as in the child. The adult would be reassured that the deficit was to be expected, based on his or her age, and told that a hearing aid, if desired, would represent an out-of-pocket expense averaging about \$4,000. Medicare provided no coverage for hearing aids. There was no robust research demonstrating meaningful consequences of hearing loss for older adults, as there was for children, and the clinical approach was typically guided by the notion that it was a very common, and hence inconsequential, aspect of aging.

But this approach didn't make sense, given what I had observed clinically. Older adults with hearing loss recounted to me their sense of isolation and loneliness, and the mental fatigue of constantly concentrating in trying to follow conversations. Family members would often describe a decline in patients' general well-being and mental acuity as they struggled to hear. For those who obtained effective treatment for their hearing loss with hearing aids or a cochlear implant, the effects were often equally dramatic. Patients spoke of re-engaging with family, no longer getting fatigued from straining to listen, and becoming their "old selves" again. If hearing was fundamentally important for children and represented a critical sensory input that could affect brain function, wouldn't loss of hearing have corresponding implications for the aging brain and its function?

Around this time, I happened across a small [study](#), published in 1989, in the *Journal of the American Medical Association* (JAMA), that suggested a link between hearing loss and the risk

of dementia. The relationship intuitively made sense to me, but the study was relatively limited in size and riddled with potential holes. For example, did older adults with hearing loss do more poorly on cognitive tests because they simply misheard what the examiner said? Or perhaps, could the co-occurrence of hearing loss and dementia be explained by a common pathologic cause? Finally, maybe hearing loss didn't contribute to dementia risk at all, but dementia led to problems with hearing (the old chicken-and-egg conundrum).

Most surprising was that in the two decades since the article was published, there hadn't been a substantive attempt to replicate these findings in a larger study that might address the limitations of the original one. Every young academic clinician is looking for a niche in which to make an impact, and I was excited to have hit upon one that could be of real importance, based on my clinical experiences.

### **From Clinical Experience to Scientific Theory**

Hunches that come from caring for patients are helpful, but scientific theories supported by evidence are a lot better. Over the past decade, my research has focused on understanding how hearing loss in older adults might contribute to cognitive decline and dementia, drawing on research done over the past half-century by giants in the disparate fields of cognitive psychology, auditory science, and other disciplines.

To elucidate the link between hearing loss and cognitive impairment, one has to start by understanding the realities of hearing and hearing loss. At the most fundamental level, our ability to hear depends on two steps—*peripheral encoding* of sound into a neural signal by the cochlea in the inner ear, and *central decoding* of the signal into meaning by the brain. The hearing loss commonly associated with aging results from accumulated damage to the cochlea that adversely affects the encoding end of the process. Because many of the cells in the inner ear that enable the cochlea to encode sounds can't regenerate, damage done by such factors as noise exposure and oxidative stress can't be undone.

With this in mind, one of the first hypothesized mechanisms linking hearing loss with impaired cognition is that hearing loss poses an additional cognitive load on the brain. We all experience that it's often harder to do two things at once—commonly called “multitasking.” (Try doing a difficult mental math problem when walking quickly.) It's not your imagination. Nearly 50 years ago, Daniel Kahneman, a psychologist and behavioral economist, who would later go on to win the Nobel Prize, postulated the idea of cognitive resource capacity—that for any individual, there's a finite pool of cognitive resources available for thinking, memory, coordinating body movements, and so on. In the years since, the implications of multitasking on cognitive performance has been well established across multiple studies.

This concept of cognitive resource capacity applies to hearing as well. When hearing is normal, sounds are encoded with high fidelity, and the resulting neural signal can be effortlessly decoded by the brain. But with hearing loss, the signal produced by the cochlea is distorted, and the decoding process requires greater cognitive effort. Research over the past several decades confirms what theory suggests: that the predicted reallocation of cognitive resources to aid in decoding sound actually occurs and comes at the expense of other cognitive abilities. Functional imaging studies on individuals with hearing loss have demonstrated that brain areas critical for higher order planning and cognitive tasks but not ordinarily used for auditory processing are being activated with auditory stimuli.

Likewise, [psychological studies](#) conducted in the 1960s and replicated numerous times since have demonstrated the impact of impoverished and garbled auditory signals on cognitive performance. Importantly, the cognitive load hypothesis suggests that hearing loss doesn't cause any actual brain pathology that leads to dementia but impacts brain function in a way that may contribute to earlier unmasking of dementia symptoms. Scientists have long known that there is not a precise one-to-one correlation between brain pathology and dementia and that various factors may buffer against brain pathology manifesting clinically. Hearing loss may be one of the factors that erodes this buffer.

But this does not exclude the possibility that hearing loss leads to pathological brain changes associated with cognitive impairment and dementia through another mechanism: auditory deprivation. Support for this hypothesis comes from experiments showing that if an animal is partially deafened, functional reorganization of the brain occurs, along with atrophy in areas that process sound. Epidemiological studies that followed older adults in the community with sequential brain scans for many years demonstrated similar findings: rates of atrophy over portions of the temporal lobe important for sound processing were accelerated in those with hearing loss. Importantly, these brain regions are also critical for other aspects of cognitive function such as semantic memory. These findings lead to the hypothesis that hearing loss may act as an additional trigger (along with common causes of dementia such as Alzheimer's and microvascular disease) for brain atrophy and other pathological changes that could directly contribute to the risk of dementia in older adults.

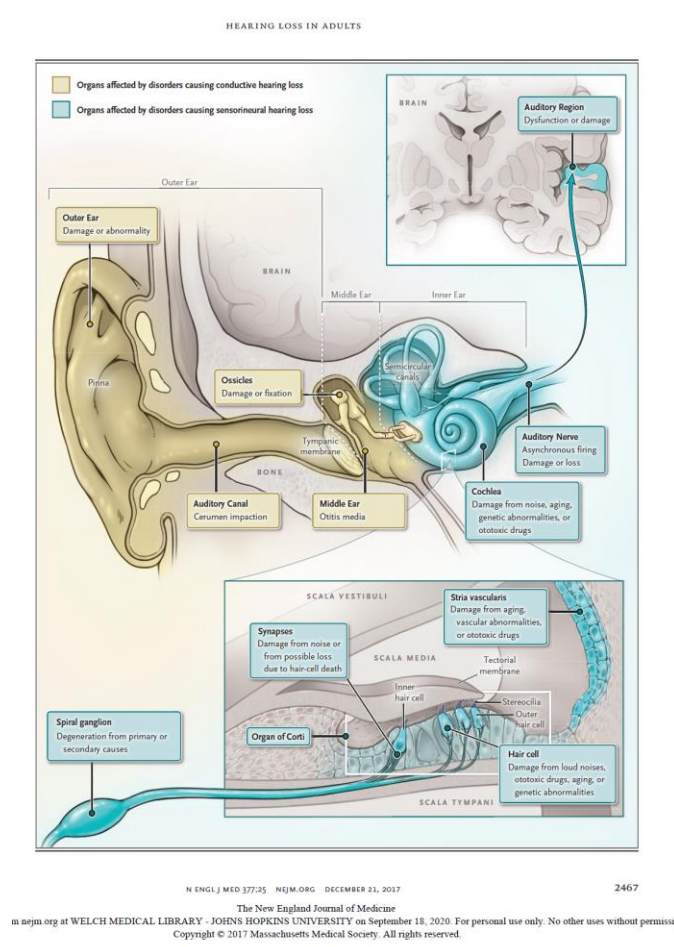
But hearing loss is more than a matter of possible effects on neural mechanism—it has a social dimension as well. A final mechanism hypothesized to explain how auditory deficits contribute to dementia relates to the social isolation and loneliness experienced by many individuals with hearing loss. While the exact mechanism through which loneliness may increase dementia risk is not yet known, there are plenty of clues, and multiple factors may be involved. Individuals who are isolated tend to be less active, more often depressed, and less likely to adhere to medical treatments—all of which could potentiate the risk of dementia over time. Most intriguingly, research over the past decade has suggested loneliness may lead to greater inflammation in the body, which would physiologically explain many of the adverse health events that have been linked with it, including heart attacks and increased [mortality](#) as well as dementia.

### **From Theory to Evidence: Correlation vs. Causation**

These mechanistic theories linking hearing loss to dementia are plausible, consistent with clinical observations, and supported by half a century of research across all fields. But even if ongoing findings continue to bear them out, does it really matter? Do these mechanisms exert

a meaningful enough impact on the risk of cognitive decline and dementia over time that hearing loss is something to worry about?

To answer this question, we must draw on large epidemiological studies that follow older adults living in the community for many years. Such studies allow us to account for factors that might explain in simple terms the correlation between hearing and dementia. For example, they may be linked by advanced age, which is strongly associated with both. Likewise, cardiovascular risk factors such as hypertension and diabetes, or general predictors of health, such as low levels of education, could potentially have negative consequences for both hearing and the brain. In a large epidemiological study consisting of hundreds to thousands of participants, we can statistically control these variables to assess whether hearing loss is an independent risk factor for dementia.



A large epidemiological study also allows us to overcome other limitations of earlier studies. By following participants over a period of many years rather than just at one point in time, we can observe if the hearing loss preceded cognitive changes (and hence may have contributed to it) rather than following after cognitive impairment. A carefully designed epidemiological study of older adults can also benefit from precise measures of hearing and cognitive function. Such studies often incorporate calibrated tests of the peripheral auditory system rather than relying solely on participants' subjective ratings of their hearing, which may be highly variable depending on personality, lifestyle, and other factors.

Rigorous protocols for the assessment of cognitive function and dementia also guard against cognitive results being biased by hearing loss. Testers are specifically trained to communicate in ways that ensure the participant's ability to hear and understand them, and testing batteries incorporate a wide range of tests (both auditory and non-auditory) to precisely assess different aspects of cognitive function such as memory, processing speed, and language abilities.

In collaboration with researchers at the National Institute on Aging, we carried out such an [epidemiological study in 2010](#) to see if we could replicate the intriguing results of the 1989 JAMA study. Using data from the Baltimore Longitudinal Study of Aging, the longest ongoing study of older adults in the U.S., we investigated whether hearing levels in a sample of adults measured in the early 1990s were associated with the risk of being diagnosed with dementia over the subsequent 15 years.

In the study, we found that individuals with mild, moderate, and severe hearing loss, respectively, had a two-fold, three-fold, and five-fold increased risk of dementia, compared to those with normal hearing. These results were surprising to us in the magnitude of the associations—we weren't seeing a modest 5-10 percent increase in dementia risk but an astronomical 100, 200 and 400 percent increase. Such an effect for a single risk factor was extremely large, and we didn't quite believe our findings (and neither did others) when the study was published in 2011.

Since then, the wheels of science have continued to turn, and other investigators who have conducted similar studies using large epidemiological datasets and precise measures of hearing and cognitive function have found comparable results. This research is perhaps best summarized in a [report published in 2017](#) by a commission on dementia convened by the journal *Lancet* to review the literature on major, potentially treatable risk factors for dementia. In this review, which was [updated in 2020](#), the authors concluded that age-related hearing loss may account for nine percent of all cases of dementia, making it the single largest, potentially modifiable risk factor for the condition, far outstripping the contribution of such well-recognized risk factors as smoking (five percent) and hypertension (two percent).

This conclusion, while striking, comes with a substantial caveat—*potentially* modifiable. Although hearing loss tops the *Lancet* list of risk factors, how much it matters depends on whether *treating* hearing loss makes an actual difference. In early studies investigating hearing-aid use in older adults, some investigators have shown a reduced risk of dementia, but these findings must be interpreted with caution: individuals who choose to use hearing aids (and more importantly, have the financial means and are sufficiently health conscious to do so) are different from those who don't use them.

Whether it's the use of hearing aids, or the factors underlying their use that drives the association with better outcomes cannot be fully disentangled even with the most sophisticated epidemiological models. To isolate the specific effect of hearing loss treatment on cognition would require a clinical trial in which a large group of older adults are randomly assigned to hearing intervention or a control condition.

I'm involved in such a trial, which is now in progress and led by the Johns Hopkins Bloomberg School of Public Health in collaboration with six other universities and supported by the National Institute on Aging and. For this trial (the Aging and Cognitive Health Evaluation in Elders ([ACHIEVE](#))), we recruited nearly 1,000 older adults in their 70s and early 80s with mild-



to-moderate hearing loss (approximately half of all older adults in this age range have such deficits) and randomly assigned them to receive hearing intervention or a healthy aging education control intervention. When this study is completed in 2023, after all participants have been followed for three years, we'll have a clearer sense of whether treating hearing loss can actually reduce cognitive decline and dementia risk.

### **Back to the Clinic**

As a practicing otologic surgeon, I see patients weekly who are concerned about their hearing and seeking advice and solutions. One question often stated bluntly is, "Doc, are you telling me that I'm going to develop dementia?" The answer, of course, is no—epidemiological studies provide insights about average effects across populations, but individual prediction is impossible. What often follows is, "Doc, will hearing aids reduce my risk of dementia, and if so, how am I going to afford them?" The answers to these questions are unsatisfying for all concerned: "We don't know yet. And I'm sorry that the costs of hearing aids are so high."

My best efforts to relieve their concerns are of little help to patients who are struggling to hear, isolated from family. As a surgeon used to making clinical decisions from a risk-benefit perspective, I also find it frustrating: hearing aids for older adults may well carry benefits for cognitive health and appear to pose zero medical risk. Wouldn't that argue for treating all older adults with hearing loss?

The problem is that while hearing aids carry no medical risk, the barriers to care are substantial. They are rarely covered by insurance, and with the average cost in the U.S. of at least \$4,000, they represent for many people the third largest material purchase in life after a house and a car. This cost is coupled with the time needed to make multiple visits to a hearing-care provider to get tested and fitted. And all this for a condition that is prevalent in nearly two-thirds of older adults over 70.

With this in mind, over the past five years, through collaborations with the [National Academy of Medicine](#) and the [White House](#) (ending in 2017), and using epidemiological data to demonstrate the potential effect of hearing loss on cognitive health in older adults, my collaborators and I have begun to have an impact on systemic policy barriers, which may ultimately reduce the personal and societal costs of treating hearing loss. Presently, only licensed healthcare professionals are allowed to sell hearing aids, according to federal regulations, and the entire worldwide hearing aid marketplace is dominated by just six companies, keeping costs high.

In 2017, the federal [Over-the-Counter Hearing Aid Act](#) was passed, which beginning in 2021 will open up the hearing aid market to the consumer technology industry, incentivizing companies like Bose and Apple to innovate and sell hearing aids and related technologies directly to consumers. In parallel, we've begun to advance federal legislation through the House of Representatives to require Medicare to cover hearing-related services.

As a clinician, I can't reduce the medical risk of hearing aids beyond zero, but our research is spurring changes to federal policies that will reduce their personal and societal costs. Between this progress and the results from the ACHIEVE trial coming in 2023, I'm hopeful that the gaping disparity between the management of pediatric and adult hearing loss that I first noted over ten years ago may start to narrow. More importantly, I'm hugely relieved that rather than providing my patients with a diagnosis that only leads to further health and financial concerns, I'll soon be able to provide them with evidence-based answers to questions they've been asking me for years and steer them toward accessible solutions.

**Bio**

**Frank R. Lin**, M.D., Ph.D., is professor and director of the [Cochlear Center for Hearing and Public Health](#) at Johns Hopkins University. As an otologic surgeon and epidemiologist, he has translated his experiences caring for older adults with hearing loss into foundational public health research and federal policy. His research established the association of hearing loss with cognitive decline and dementia, and he now leads two ongoing, National Institutes of Health-funded randomized trials that are evaluating the efficacy of hearing interventions. In parallel, Lin has collaborated with the National Academies, the White House, and Congress to develop policies to ensure hearing loss can be effectively and sustainably addressed in society.